Use of CrIS Radiances at NOAA

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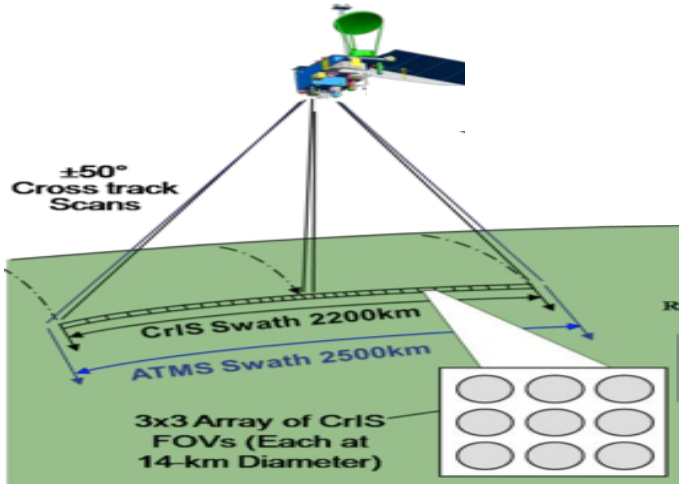
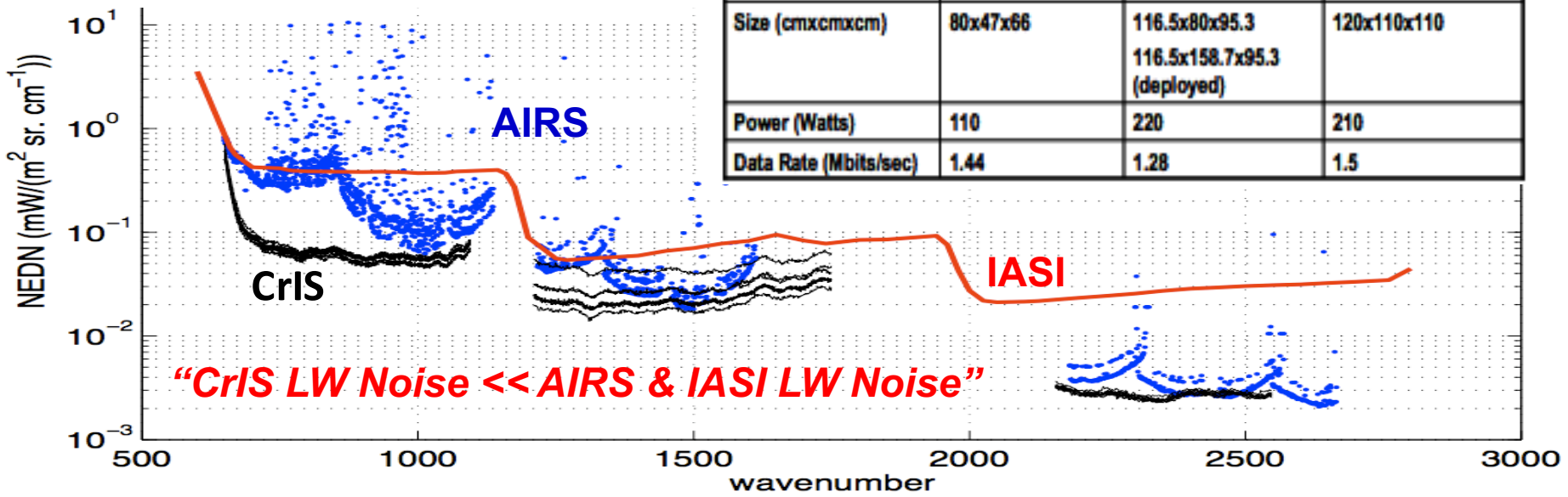
Cross-Track Infrared Sounder (CrIS)

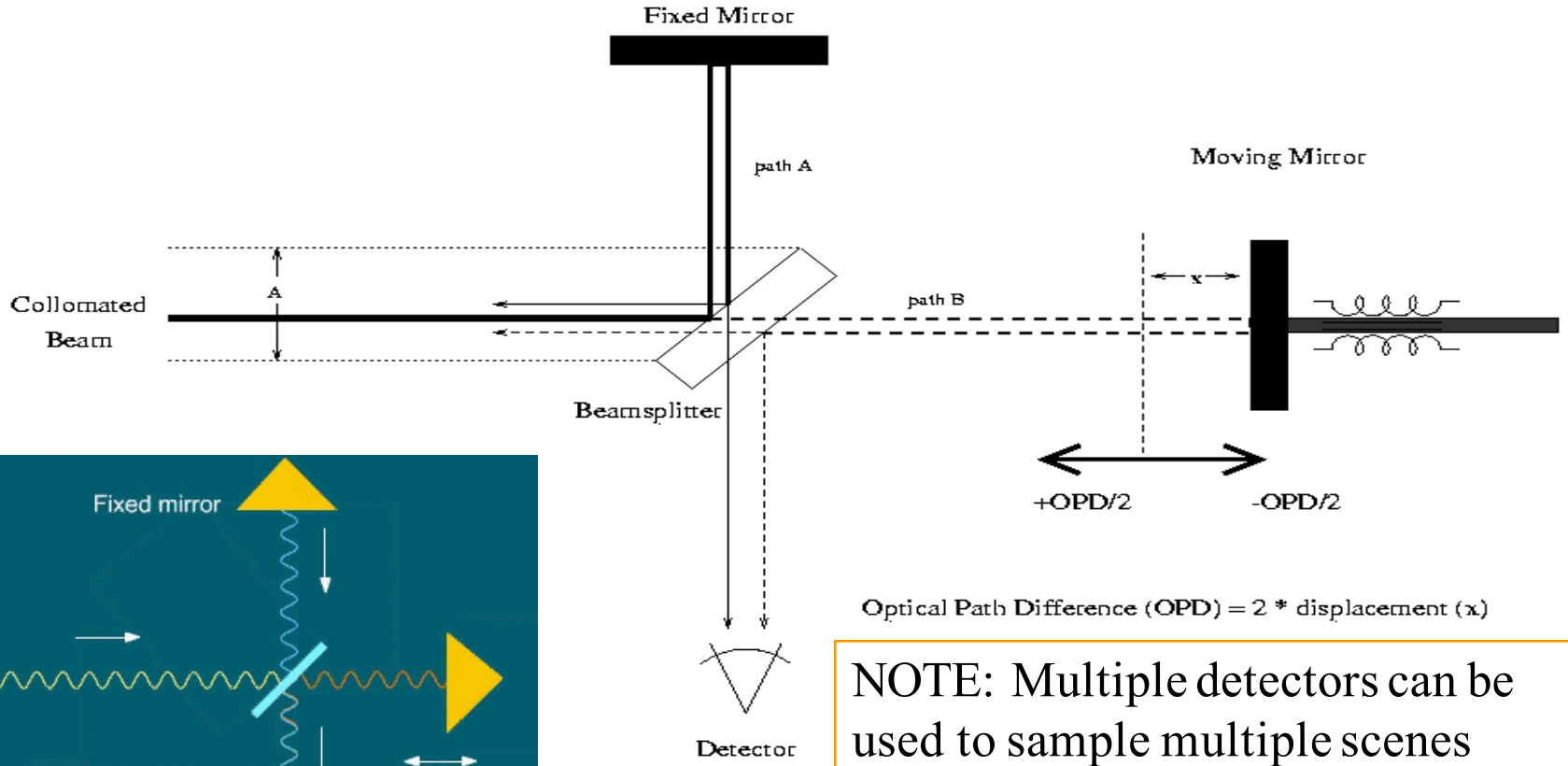


- Michelson Interferometer
- Spectral range: 650 to 2550 cm^{-1}
- Three bands, each a 3 x 3 HdCdTe focal plane
- Cooling: passive, 4-stages, 85K
- Radiometric Calibration: 310 K Blackbody and cold space view
- Low noise, NEDT ranges from 0.05 K to 0. 5 K

	CrIS (on NPP)	AIRS (on EOS Aqua)	IASI (on MetOp)
Weight (kg)	147	177	236
Size (cmxcmxcm)	80x47x66	116.5x80x95.3 116.5x158.7x95.3 (deployed)	120x110x110
Power (Watts)	110	220	210
Data Rate (Mbits/sec)	1.44	1.28	1.5



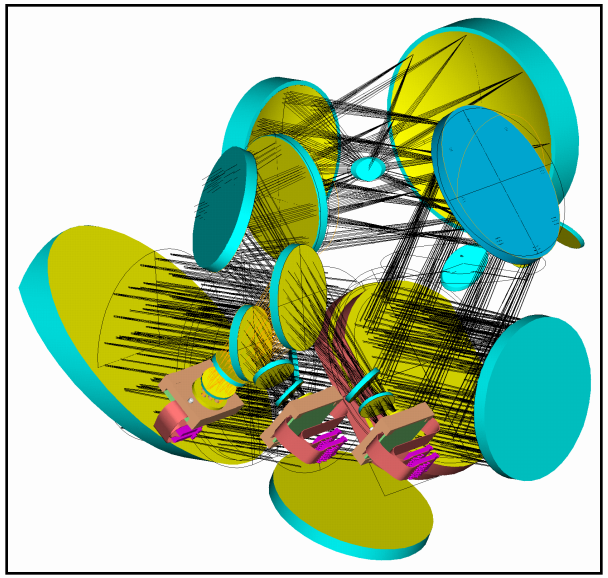
CrIS (and IASI) use an Interferometer
(graphic shows a simplified Michelson Interferometer)

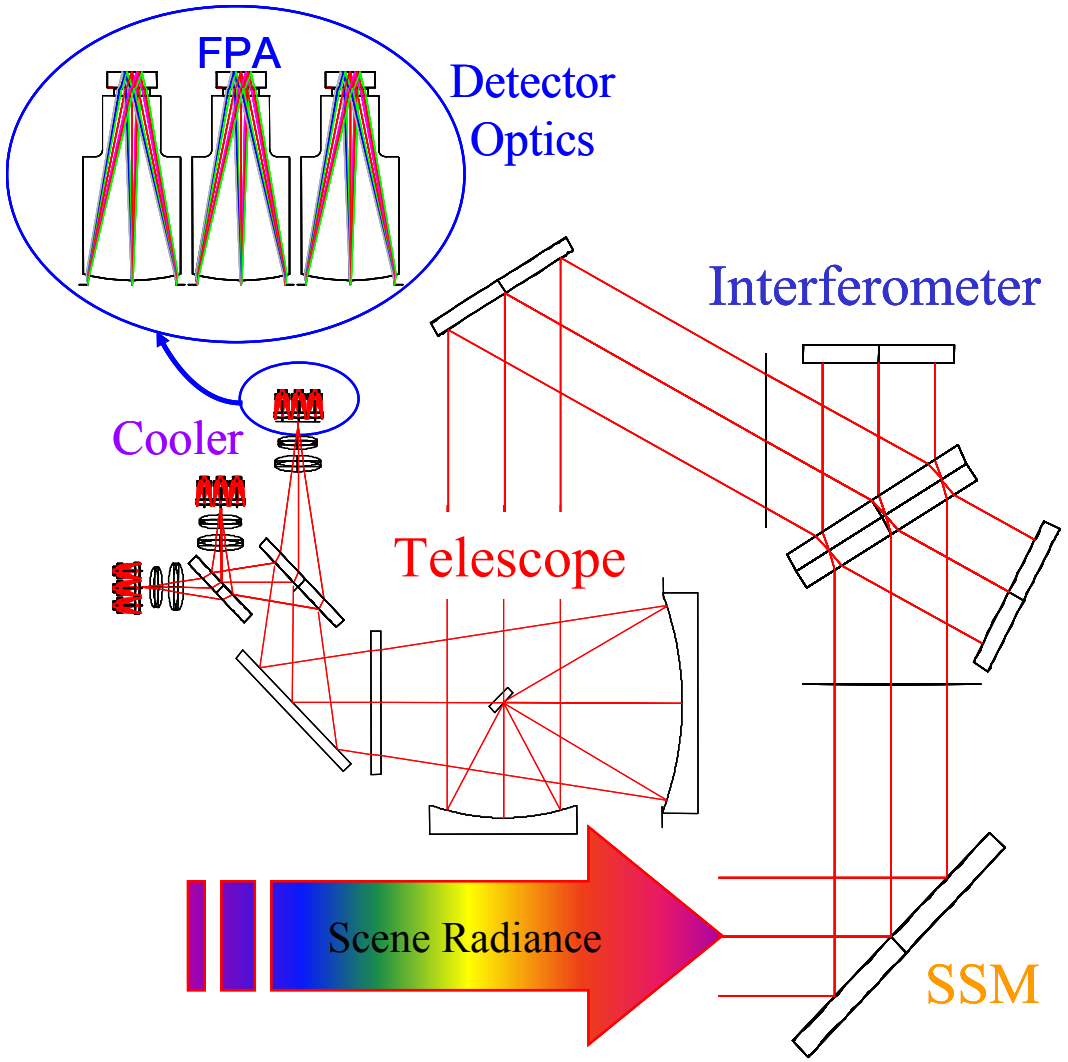


NOTE: Multiple detectors can be used to sample multiple scenes simultaneously. Each detector can be Fourier transformed into many spectrial "channels" in the infrared

CrIS Optical System

- Extremely Compact
- Large Aperture (8 cm)
- Excellent Image Quality
- Fully Wedged / Tilted
- Athermalized Design
- Pupil Imaging System

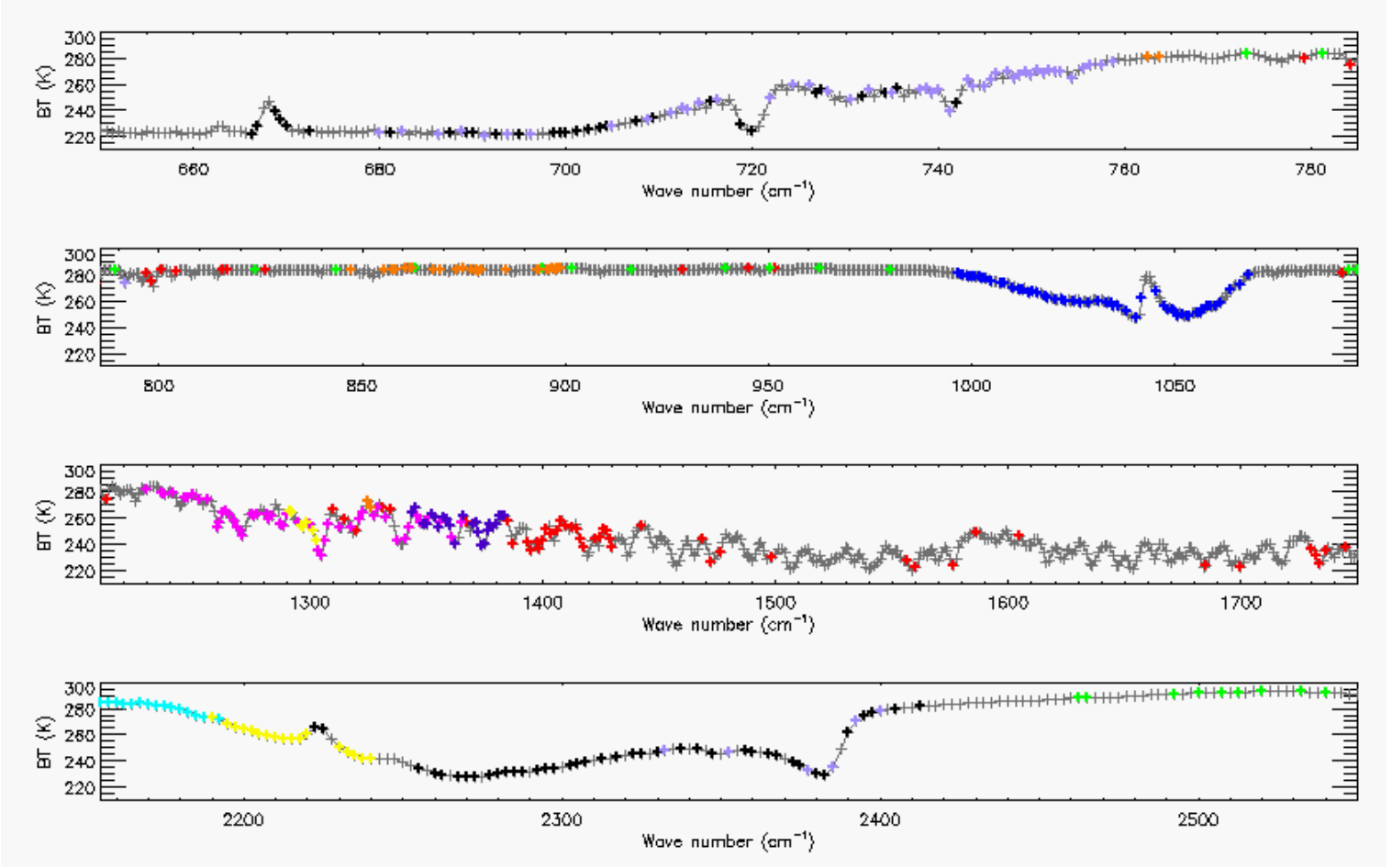




Slide courtesy of Joe Predina
ITT/Exelis, May 6, 2009

NOAA NESDIS Normal Spectral Resolution (NSR) CrIS channel selection (399/1305 channels)

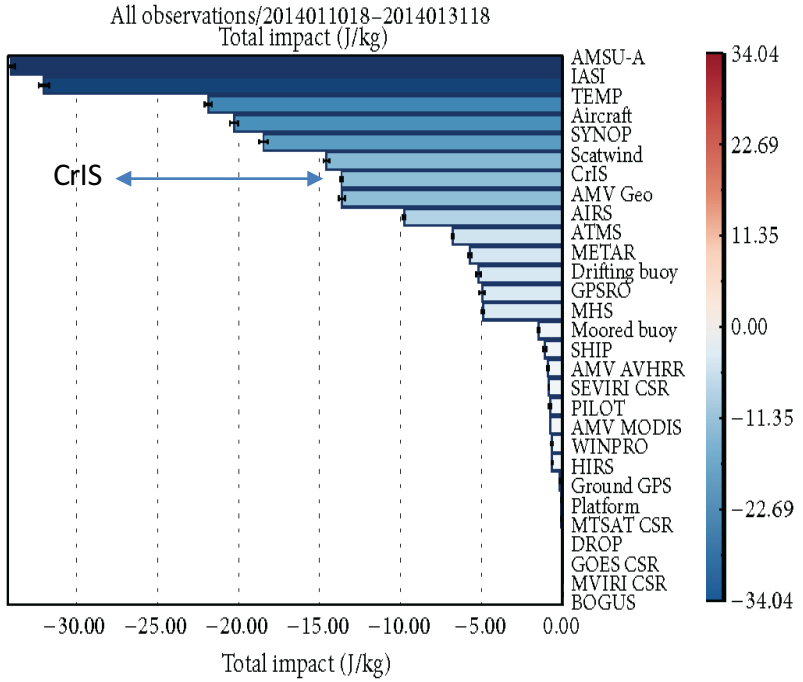
EDR	#chns
Temp	87
Surf	24
H2O	62
O3	53
CO	27
CH4	54
N2O	24
SO2	54
HNO3	28
CO2	53



REF: A. Gambacorta and C. Barnet., Methodology and information content of the NOAA NESDIS operational channel selection for the Cross-Track Infrared Sounder (CrIS), IEEE, Vol. 51, Issue 6, 2013

Use of CrIS in Data Assimilation (UKMet Results)

- Data assimilation systems use a subset of channels
  - Use a subset of ~60-100 channels (the "Temp" chls)
  - For each scene retains the ones unaffected by clouds
    - If scene is clear then all subset channels are retained
    - ~5% of FOV's are clear
- For UKMet: Impact of 5-AMSU's > 2-IASI's > CrIS > AIRS > ATMS

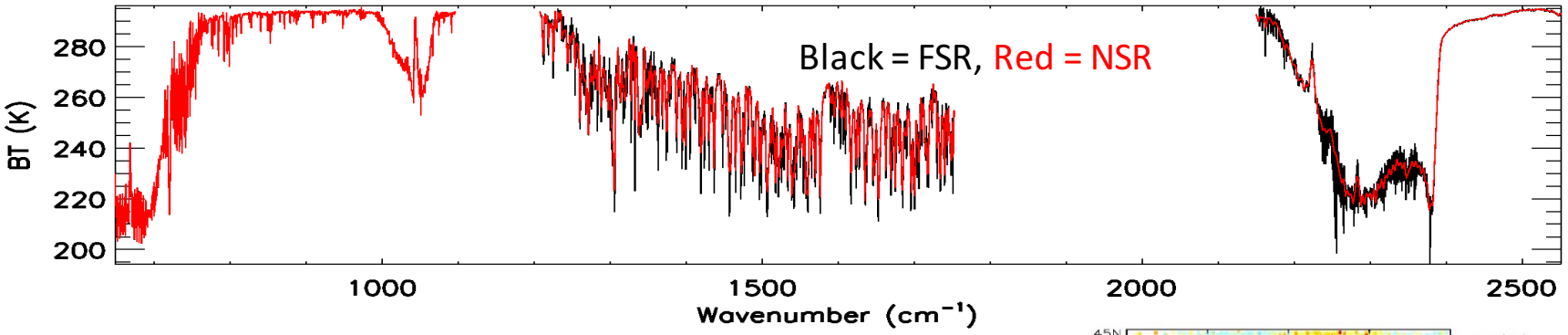


From Doherty 2015 Adv. Met.

1. CrIS adds value and has slightly more impact than AIRS and slightly less than the two IASI's
2. Also adds value to ATMS and the 5 AMSUs used in the system

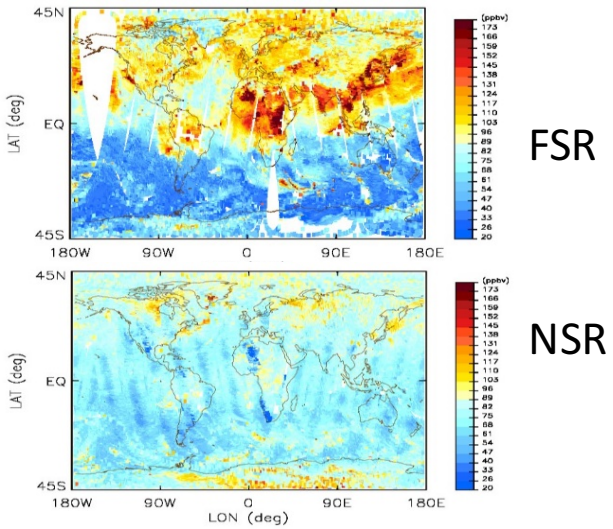
CrIS Full Spectral Resolution (FSR) Mode

In NSR mode, CrIS truncates mid-wave to 0.4 cm OPD and short-wave to 0.2 cm OPD
On Dec. 4, 2014 – CrIS was switched to FSR model (all 3 bands are 0.8 cm OPD)



Benefits of full spectral resolution:

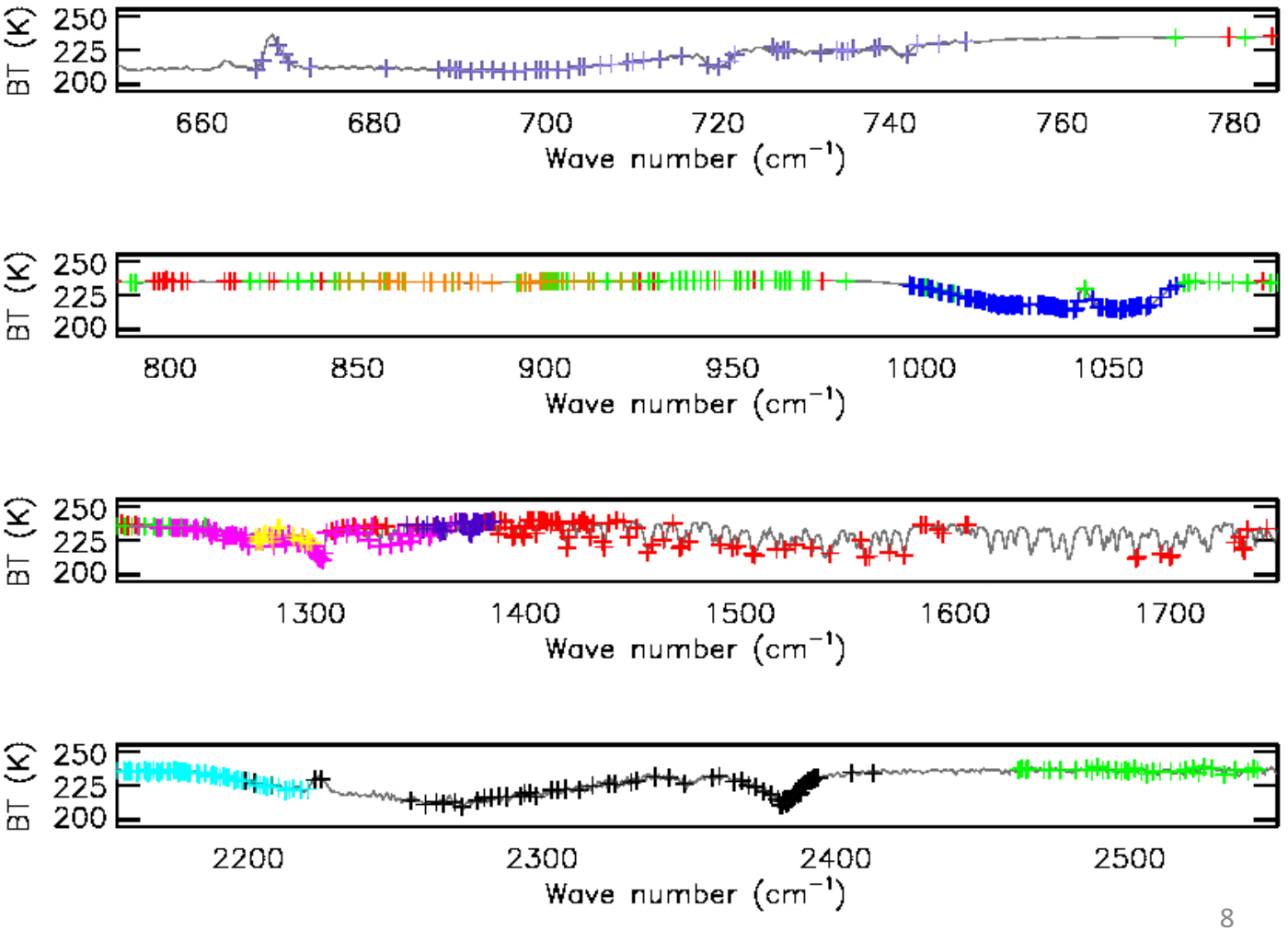
- Carbon monoxide retrieval becomes viable
  - Useful for air quality application
- Resolve weak water vapor spectral lines to improve upper troposphere water soundings
- Better calibration of 4.3 um band improves lower tropospheric temperature



2/17/2015 carbon monoxide

NOAA NESDIS Operational FSR CrIS channel selection (610/2211 channels)

EDR	#chns
Temp	116
Surf	136 (62)
H2O	123 (62)
O3	77
CO	52
CH4	84
N2O	21
SO2	31
HNO3	30
CO2	50 (T LW)

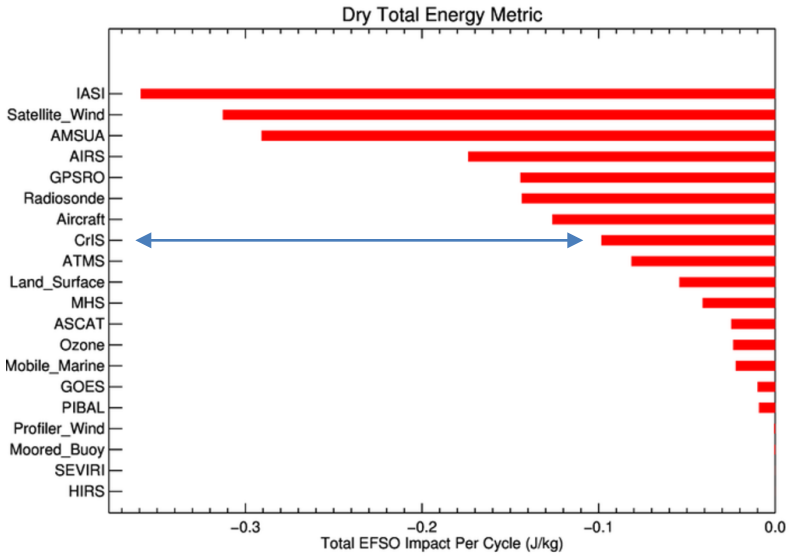


NCEP Use of CrIS: Control Run (Preliminary Results)

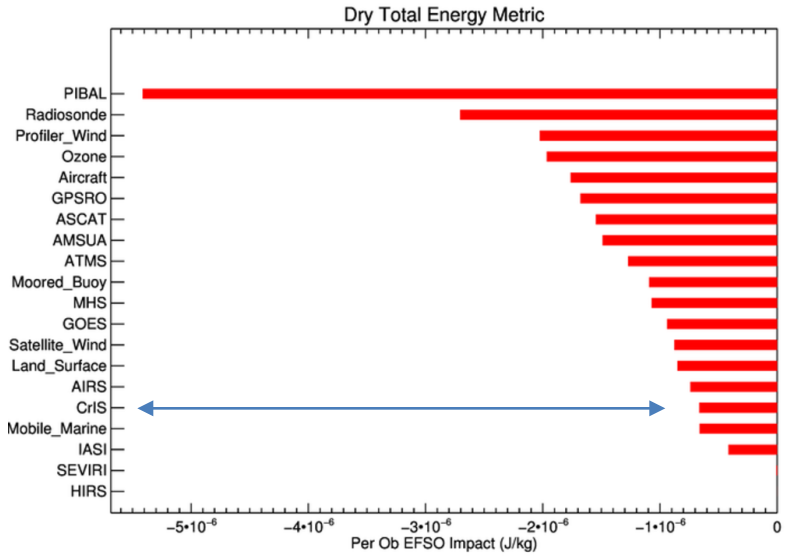
Courtesy of Jim Jung (JCSDA)

- Used 84 T(p) NSR channels from LW band

Total Impact



Per Observation



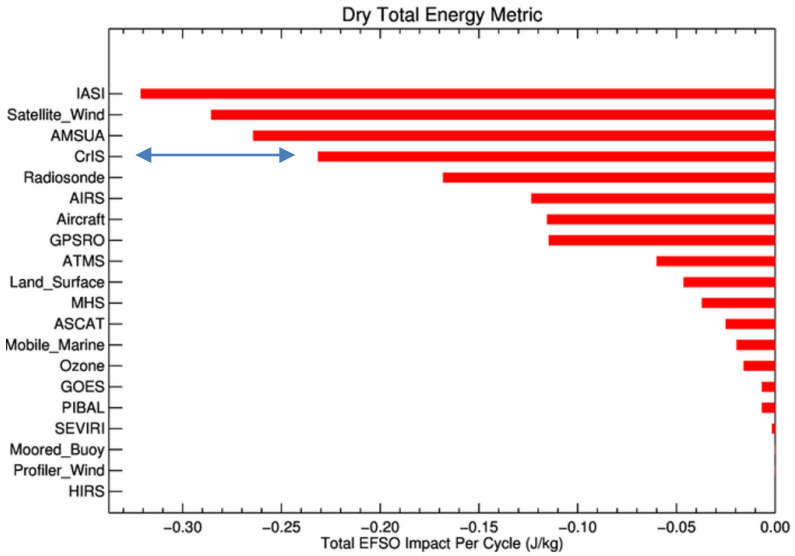
- Similar ranking of CrIS as UKMet system (on p.6)
  - 2-IASI > 5-AMSU > AIRS > CrIS > ATMS

NCEP Use of CrIS: Experiment (Preliminary Results)

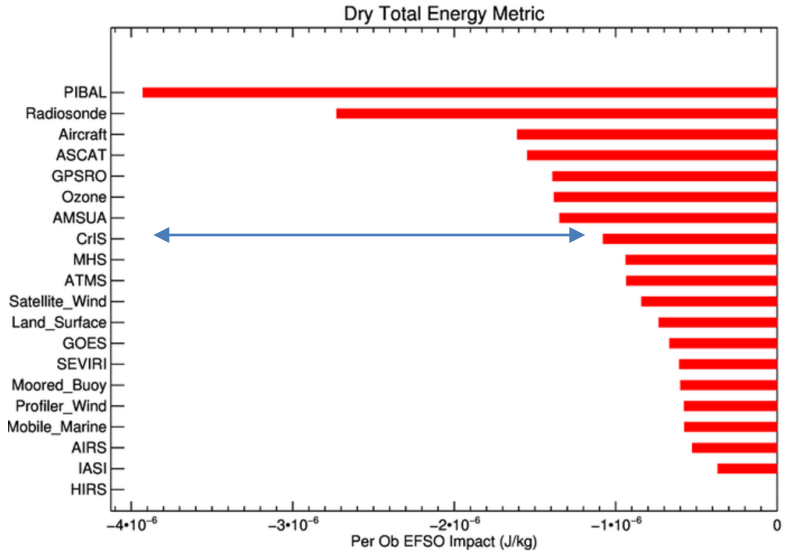
Courtesy of Jim Jung (JCSDA)

- 102 FSR channels, 94 T(p) and 8 WV
  - Numerous other internal modifications and use of VIIRS cloud information

Total Impact



Per Observation



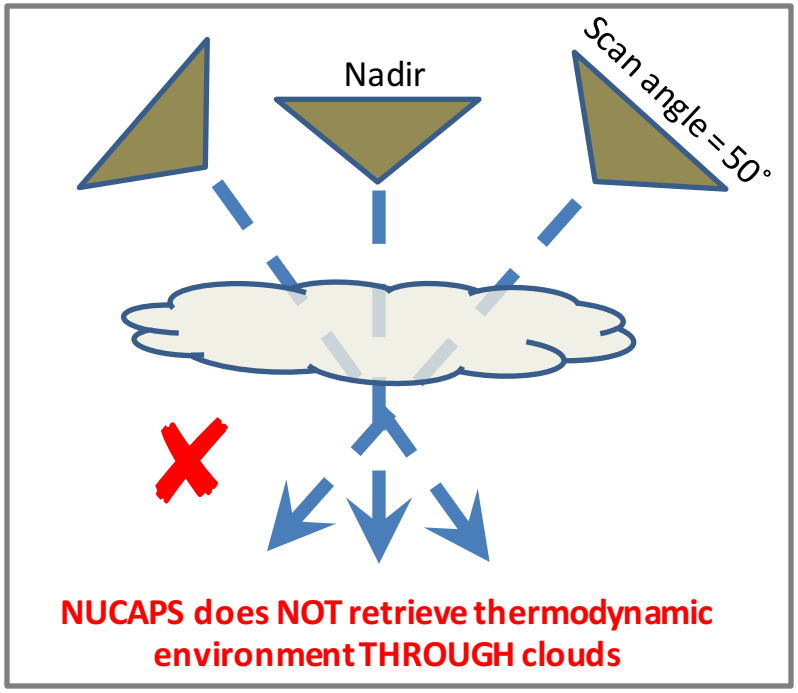
- CrIS impact ranking has improved
  - 2-IASI > 5-AMSU > CrIS > AIRS > ATMS

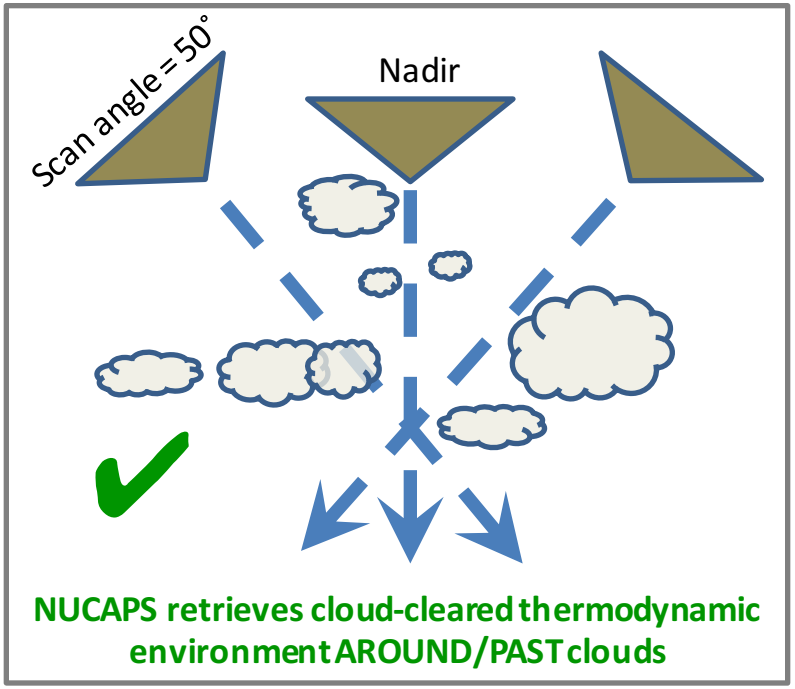
Is there a better way to deal with clouds?

To an Infrared Sounder (CrIS) even a small amount of cloud is an obstacle.

NUCAPS performs "cloud clearing" to increase the yield of quality soundings

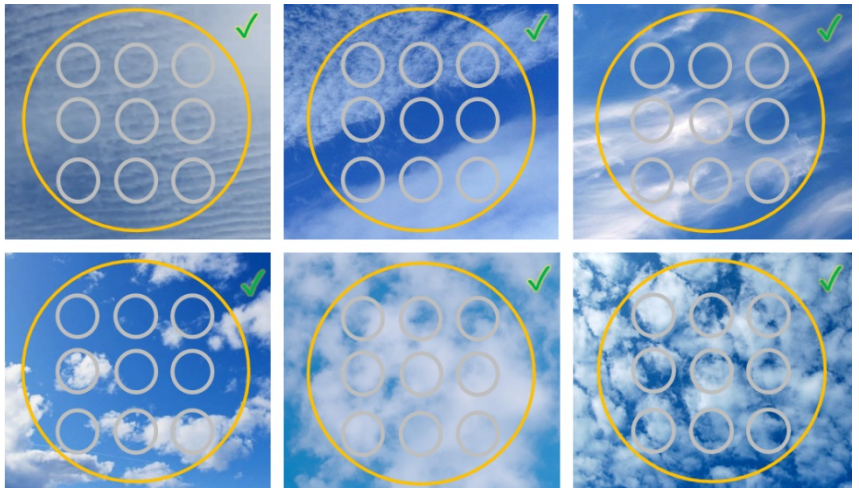
The goal is to provide soundings in difficult meteorological situations …..
and ….. as close to the surface as possible





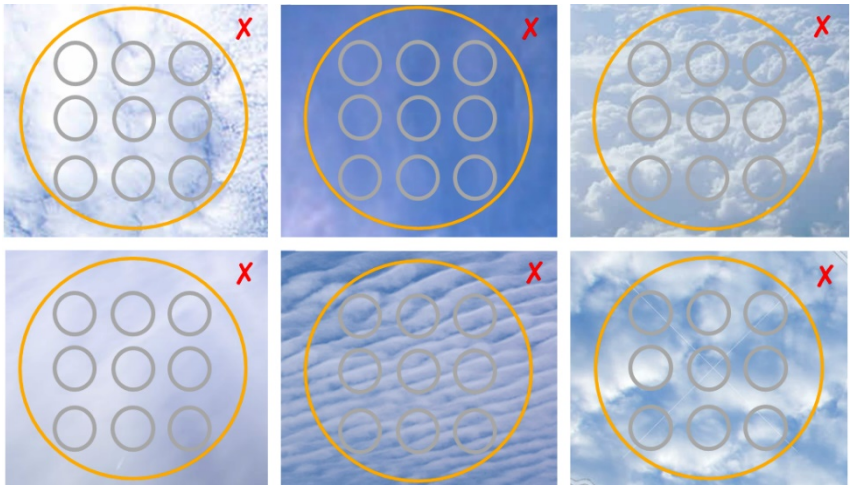
NUCAPS uses cloud clearing to retrieve soundings in partially cloudy scenes

Cloud Clearing **succeeds** when NUCAPS footprint has **cloud variability**; i.e. when the CrIS footprints have variable cloud fractions



~2% probability a CrIS FOV is clear
~5% probability a CrIS FOR is clear
But ~70-80% of scenes can be cloud cleared
→ even if no single FOV is clear

Cloud Clearing **FAILS** when NUCAPS footprint is **uniformly cloudy**, *i.e.* when each CrIS FOV has the same cloud fraction



Scene does not have to be overcast

Even a small amount of *uniform* clouds needs to be rejected

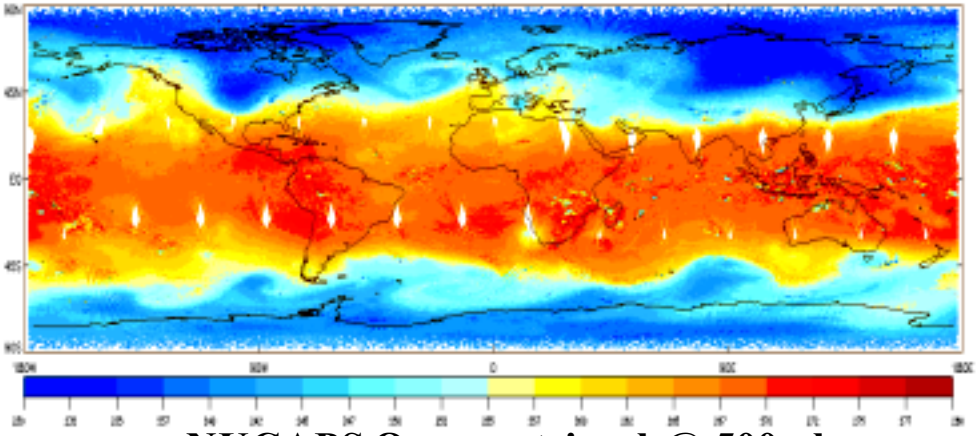
NUCAPS field of regard (FOR) = set of 9 CrIS field of view (FOV)

List of operational and experimental NUCAPS retrieval products

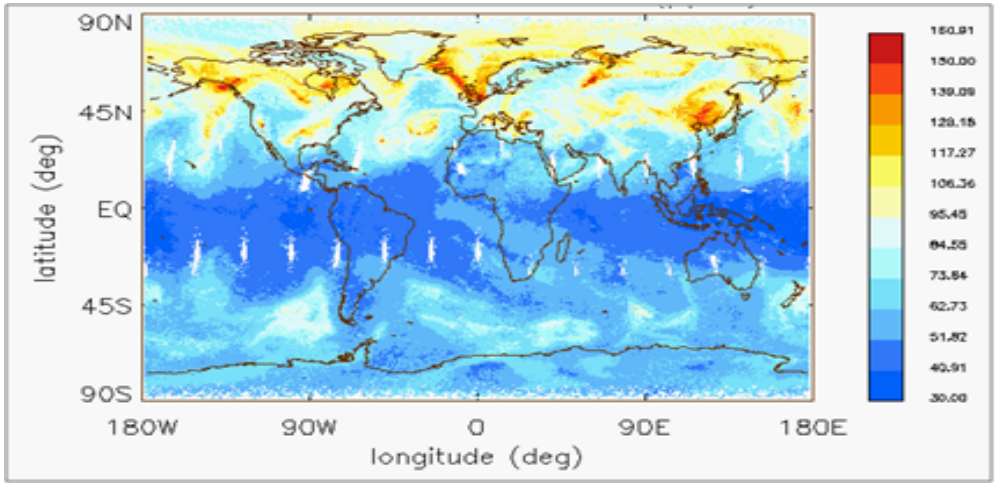
Retrieval Product	Spectral Region Used (cm^{-1})
Cloud Clearing Parameters (4 *linear* parameters)	660 – 750 2200 – 2400
Cloud fraction and Cloud Top Pressure and Temperature	660 - 750
Surface temperature (LST, SST), emissivity and solar reflectivity	800 – 950, 1210 – 1230, 2400 - 2550
Temperature, T(p)	660 - 750 2200 - 2400
Water Vapor, q(p)	780 – 1090 1200 - 1750
Ozone, O_3(p)	990 – 1070
Carbon Monoxide, CO(p)	2155 – 2220
Methane, CH_4(p)	1220 - 1350
Carbon Dioxide, CO_2(p)	660 – 760, 980, 2200 - 2400
Nitrous Oxide, N_2O(p)	1290 - 1300 2190 - 2240
Nitric Acid, HNO_3(p)	760 - 1320
Sulfur, Dioxide, SO_2(p)	1343 - 1383

NUCAPS Temperature retrieval @ 500mb

(January 5th 2014 Polar Vortex Anomaly)



NUCAPS Ozone retrieval @ 500mb

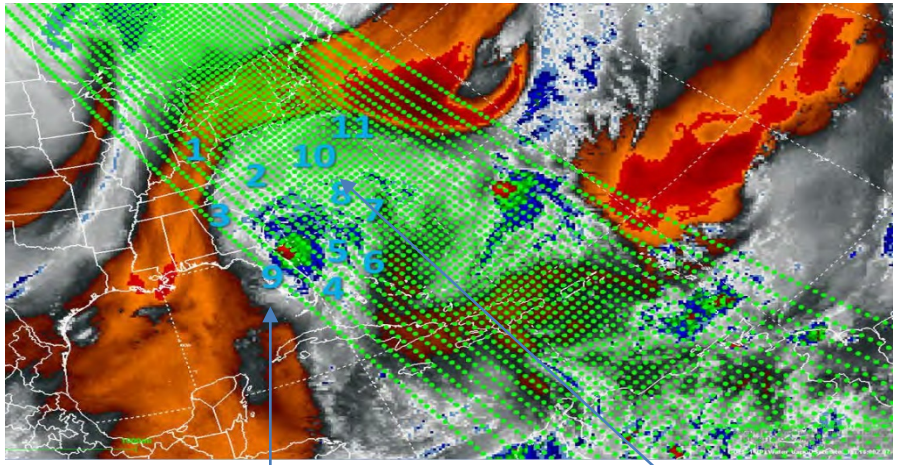


Applications in WPC/AWIPS-II
Extratropical Transition

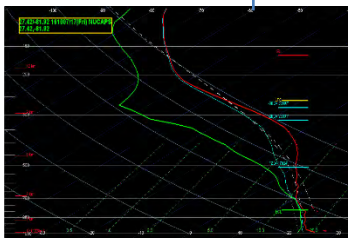
- Emily Berndt, NASA SPoRT, is working with the JPSS Proving Ground and the National Hurricane Center to testbed the utility of NUCAPS CrIS/ATMS Soundings to anticipate hurricane tropical to extratropical transition
  - Uses temperature, water vapor and ozone
  - Complements the Air Mass RGB w/ vertical information
- Satellite soundings can provide valuable information in data sparse regions about the depth of moist or dry layers of the atmosphere which are important for anticipating changes in storm intensity
- At right, the location of NUCAPS (green dots) on GOES-13 WV for Oct. 7, 2016
  - NUCAPS profiles show vertical extent of moisture (compare region #9 and #10)
  - Ozone and tropopause height show influence of stratospheric intrusions

"I would also be interested in something similar for Hurricane Nicole right before it strengthened. Both of these TCs intensified, one of them very rapidly, in fairly high shear environments… - MD"

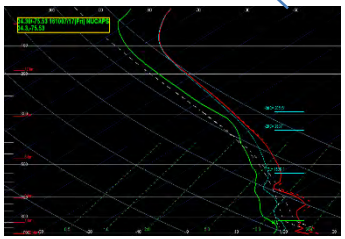
Hurricane Matthew GOES Water Vapor and NUCAPS Soundings



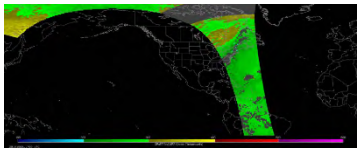
Profile #9



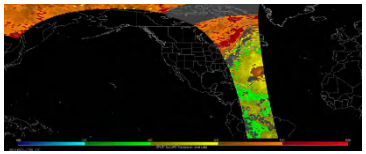
Profile #10



Ozone



Tropopause Height

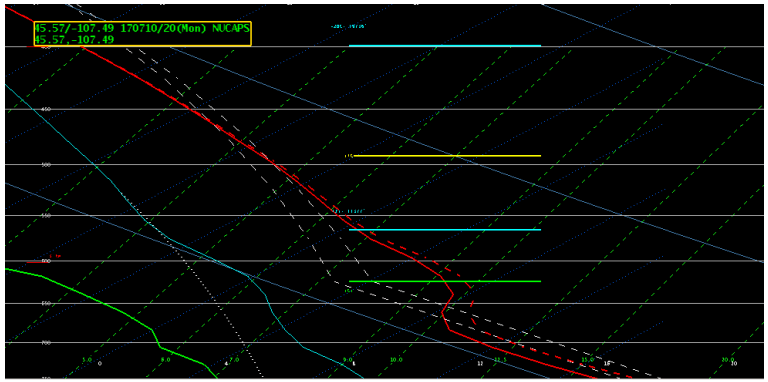


Spring experiment 2017 Blog Post

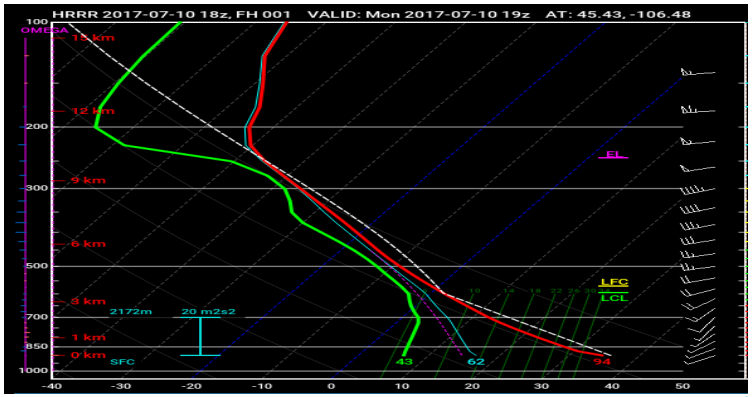
http://goesrhwt.blogspot.com/search/label/NUCAPS

- July 10, near Billings Montana a noticeable inversion was detected near/just above 700mb
  - HRRR, RAP, and NAM soundings was unable to detect this feature
  - smoke plume visible near Birney, Montana, radar indicates 9800' AGL
  - nearest NUCAPS sounding to the fire, inversion was ~8300' AGL
- As convection pushed eastward it's intensity decreased
  - Consistent with inversion
- NUCAPS soundings have no influence from the model (except surf pressure)
  - Have no convective or cloud models.
  - Forecasters are learning the pro's, and the con's, of these satellite soundings
  - We are improving the training and the soundings, as a result of this feedback

NUCAPS Sounding nearest the fire (~19:30z, Birney, MT) (zoomed)

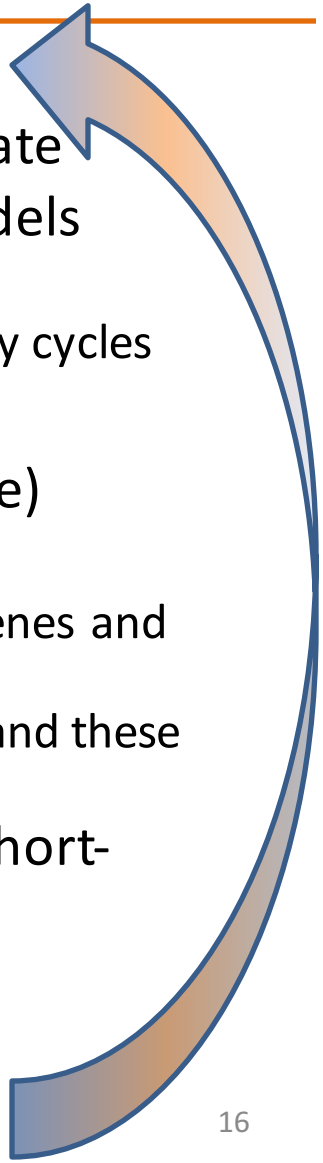


HRRR Sounding valid at 19z (18z initialization), NOTE scale difference



Is there another reason to study Soundings?

- Data assimilation (DA) ingests many instruments
  - Microwave (*e.g.*, ATMS) is easier (more linear) to assimilate
  - Infrared (*e.g.*, CrIS) may be under-utilized in all NWP models
    - Ignore many channels that have useful information
    - Assume obs. will nudge model in the right direction over many cycles
- Retrievals operate on single satellite field of regard
  - Can do detailed calculations (*e.g.*, off-diagonal covariance)
  - CrIS+ATMS can provide soundings in ~70-80% of scenes
    - Use of cloud clearing significantly increases the number of scenes and the number of channels used, especially near surface
    - Cloudy scenes are more likely to include interesting weather and these scenes are more likely to have a positive impact on the model
  - We use many more channels: water vapor, trace gases, short-wave (day or night), "window" regions, etc.
    - Goal is to maximize signal-to-noise of observation
- Retrievals are the same science as DA analysis
  - lessons learned may be relevant to global models



QUESTIONS?